U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-256 926

Report on a Study of the Weber County Incinerator in Ogden, Utah

Bureau of Solid Waste Management

1970

BIBLIOGRAPHIC DATA SHEET	1. Report No. TO-3.1.001/8	2.	3. Recipient's Accession No. PB-256 926
4. Title and Subtitle Report on a Study of thw Weber County Incinerator in Ogden, Utah			5. Report Date 1970 6.
7. Author(s) Jerry E. Ongerth, and Morris G. Tucker			8. Performing Organization Rept. No.
9. Performing Organization Name and Address Bureau of Solid Waste Management Cincinnati, Ohio			10. Project/Task/Work Unit No. 11. Contract/Grant No.
12. Sponsoring Organization Name and Address			13. Type of Report & Period Covered 14.

15. Supplementary Notes

16. Abstract
An incinerator discharges effluents into the environment in three states: solid, liquid, and gaseous. The sources of these effluents are the processes of combustion, gas cleaning, and residue quenching. Any determination of the pollution contribution to the environment by incineration must be concerned with all these effluents. The Bureau of Solid Waste Management has initiated a program to characterize the performance of incinerators of different designs and configurations. The primary objectives of the program are to produce basic information that identifies the results of the incineration process and to develop reliable sampling methodology. The Weber County Incinerator at Ogden, Utah is designed to handle 300 tons per 24 hour day of solid waste with a gross heating value of 5000 Btu per pound. During the period of this study the furnaces burned an average of 5.7 tons of solid waste per hour per furnace or 91 percent of the design rate.

17. Key Words and Document Analysis. 17a. Descriptors
*Solid waste disposal,
*Incinerators,
*Air pollution abatement,

Design,
Sampling,
Combustion,
Residues,
Fly ash,
Flue gases,
Chemical analysis
Scrubbers,
Measuring instruments,
Instrumentation,
Burning rate,
Laboratory equipment,
Cost analysis,
Utah.

17b. Identifiers/Open-Ended Terms
Air pollution sampling,
Ogden(Utah).

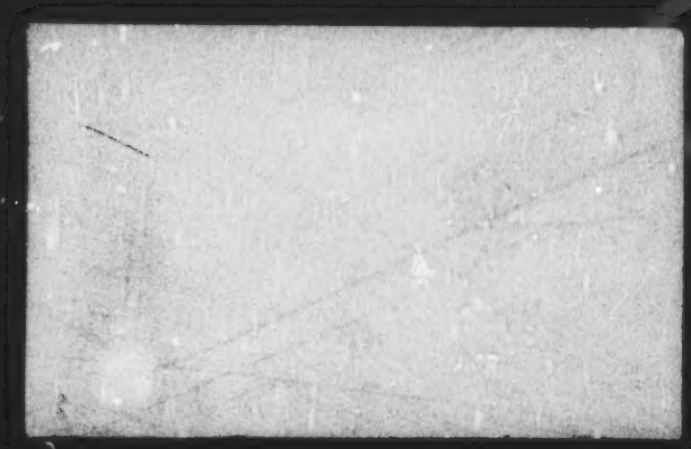
17c. COSATI Field/Group 13 B 7 D

18. Availability Statement
National Technical Information Service
Springfield, Virginia 22161

19. Security Class (This Report) UNCLASSIFIED
20. Security Class (This Page) UNCLASSIFIED
21. No. of Pages 50p
22. Price 4.00/2.25

FORM NTIS-35 (REV. 10-73) ENDORSED BY ANSI AND UNESCO. THIS FORM MAY BE REPRODUCED USCOMM-DC 8265-P74

PB 256 926



REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U. S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

REPORT

ON A STUDY OF THE WEBER COUNTY INCINERATOR

IN OGDEN, UTAH

A *Division of Technical Operations Open-File Report* (TO 3.1.001/8)
written by JERRY E. ONGERTH *and* MORRIS G. TUCKER

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Environmental Health Service
Bureau of Solid Waste Management
1970

BACKGROUND

Incineration is an important method of solid waste processing in the United States, and although over 300 incinerators are in operation, little information on the performance of these units is available. It is therefore not surprising that the effects of incineration on the environment are little understood and frequently ignored.

An incinerator discharges effluents into the environment in three states: solid, liquid, and gaseous. The sources of these effluents are the processes of combustion, gas cleaning, and residue quenching. Any determination of the pollution contribution to the environment by incineration must be concerned with all these effluents.

The Bureau of Solid Waste Management, through the Division of Technical Operations, has initiated a program to characterize the performance of incinerators of different designs and configurations. The primary objectives of this program are to produce basic information that identifies the results of the incineration process and to develop reliable sampling methodology.

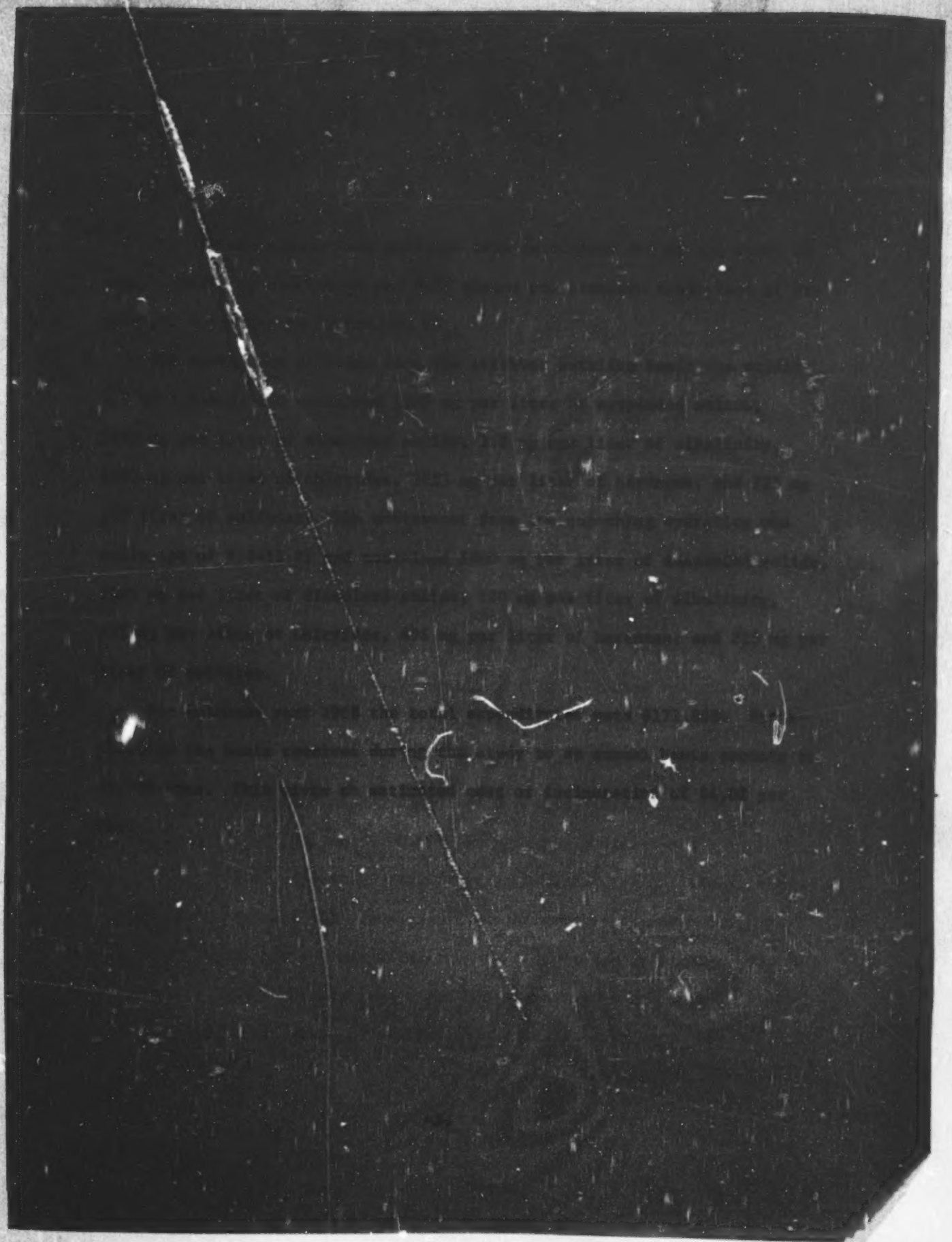
During the studies it is considered necessary to make a complete analysis of all features that affect the operation of the facility as well as those that influence its potential for environmental pollution. The operation of the facility is not altered in any way unless specific study objectives dictate a change. Therefore, no special effort is made to operate the facility at its design capacity; rather, it is tested at its "operating" capacity.

Reports from each study in this program will be prepared primarily for use by the management of the facility. Each report will contain only the data obtained during one individual study. Data comparisons with other studies will not be made in individual study reports. Summaries and comparisons of the data from all studies will be reported annually.

TABLE OF CONTENTS

	Page
SUMMARY	1
INTRODUCTION	3
DESCRIPTION OF FACILITY	4
General	4
Design	6
Furnaces	6
Residue Handling	10
Combustion Air	10
Fly Ash Scrubbing	11
Instrumentation	12
Operation	12
METHODS AND PROCEDURES	15
Solid Waste	15
Furnace Residue	16
Liquid	16
Stack	17
Fly Ash	17
Laboratory Procedures	17
RESULTS AND EVALUATION	19
Solid Waste	19
Burning Rate	23
Residue	24
Fly Ash	25
Plant Efficiency	26
Particulate Emissions	27
Liquid Effluents	27
Cost Analysis	31
REFERENCES	35
ACKNOWLEDGMENTS	36
APPENDICES	37

		Page
Figure 1	Weber County, Utah Incinerator, General Layout	5
Figure 2	Weber County, Utah Incinerator, Side Elevation Schematic	7
Figure 3	Weber County, Utah Incinerator, Combustion Unit Schematic	8
Table		
1	Solid Waste Received	19
2	Weight of Solid Waste Component Per Sample	20
3	Percentage of Solid Waste Component Per Sample	21
4	Composition of Solid Waste Samples Returned for Proximate Analysis	22
5	Proximate Analysis of Solid Waste	22
6	Burning Rate	24
7	Residue Composition	25
8	Proximate Analysis of Residue	26
9	Plant Efficiency	26
10	Stack Effluent Data Per Furnace	28
11	Wastewater Characteristics	29
12	1968 Incinerator Costs	32
13	Operating Cost Breakdown by Cost Centers	33
14	Repair and Maintenance Cost Breakdown by Cost Centers	34



INTRODUCTION

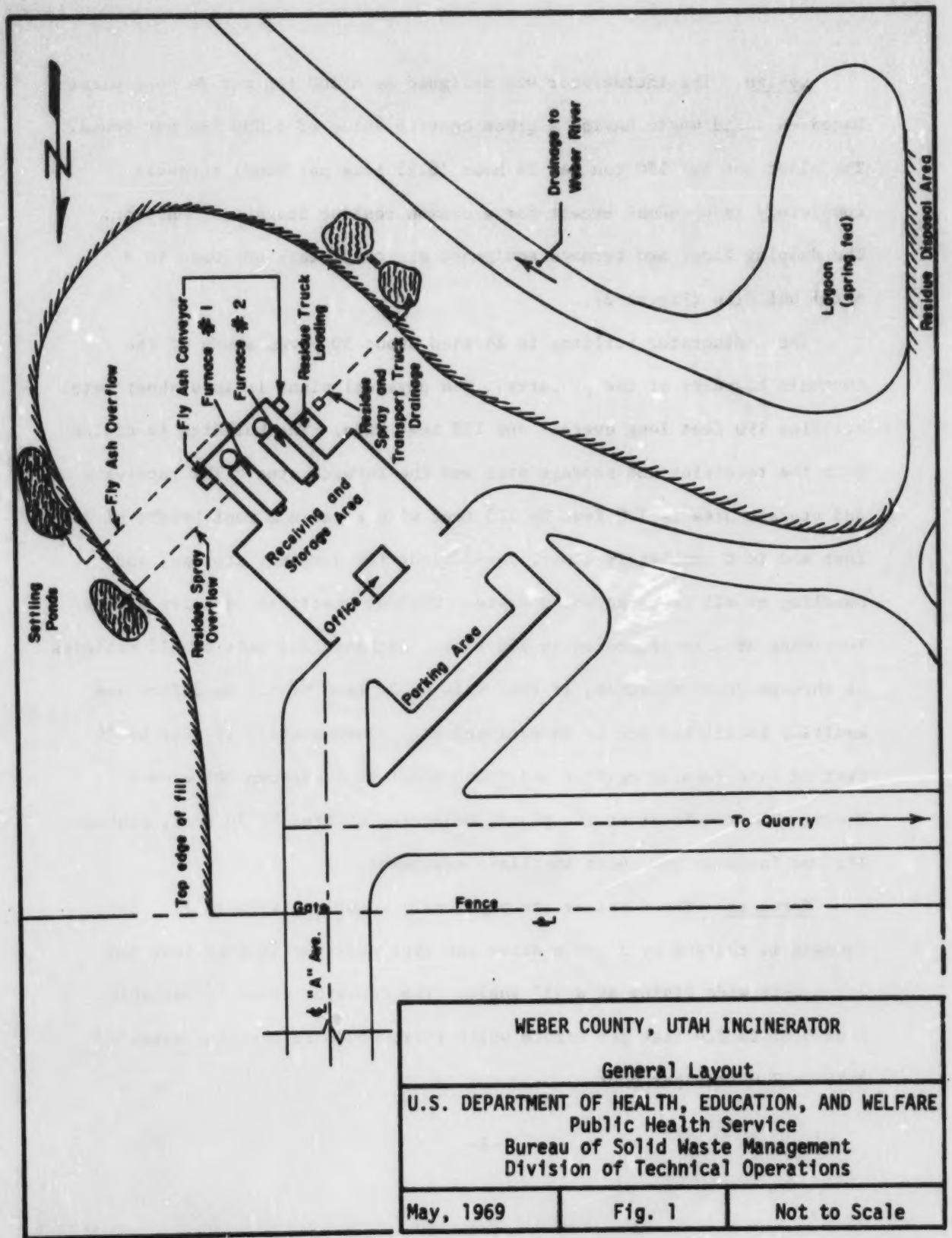
The Utah Division of Health and the Weber County Board of Commissioners were interested in determining the characteristics of the liquid, gaseous, and solid effluents from the Weber County Incinerator. Construction of the incinerator was authorized by the County Commissioners with the understanding that the plant design would include features which were unique and would serve to facilitate efficient combustion of municipal solid wastes to nuisance free products in a sanitary manner at a cost per ton significantly lower than average figures reported in the literature.

Since this incinerator departed substantially in configuration and capital investment for a municipal size facility, the Bureau of Solid Waste Management was requested to conduct a study during the period of April 20-26, 1968. On June 17, 1968, a preliminary report of the study was submitted to the State and County and was followed with a meeting on July 10, 1968, to discuss the results.

DESCRIPTION OF FACILITY

General. The Weber County Incinerator, 2599 A Avenue, Ogden, Utah, is owned and operated by the county. Construction was completed in December 1966 and operation began immediately. The incinerator is the primary solid wastes processing facility for the lower valley area of Weber County. It receives municipal and private collections of residential, commercial, and industrial solid wastes generated within this area. This area is approximately 12 by 15 miles in size and has a population of 120,000. The incinerator site is 1.4 miles from the center of population estimated by the county as being located at 24th and Washington in the city of Ogden. The average haul distance on a ton-mile basis is approximately 4 miles. There is a charge of $0.50 per household per month to support the facility.

The incinerator is situated on a 5 acre plot bordered on the north by residential West Ogden (Figure 1). Adjacent to the plant on the southwest is a 30 acre residue and fly ash disposal site. The pit varies in depth from 40 to 60 feet and, as presently operated, has a life expectancy estimated at approximately 200 years. The haul distance from the incinerator to the disposal site is less than a quarter of a mile. The site is part of a quarry operation and sand is available for cover material. The northern boundary of the incinerator property is bordered by a chain link fence with a lockable gate at the A Avenue entrance which is the only entrance to the facility. County road department dump trucks using the quarry at the west end of the property also regularly enter this gate.



WEBER COUNTY, UTAH INCINERATOR

General Layout

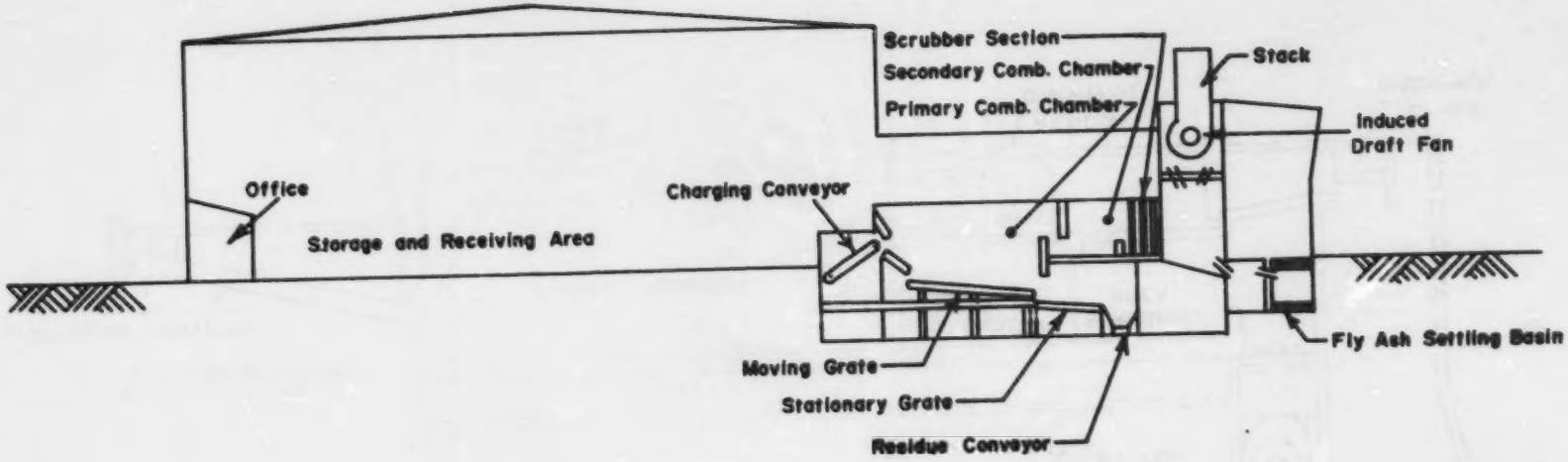
U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Bureau of Solid Waste Management
Division of Technical Operations

May, 1969	Fig. 1	Not to Scale

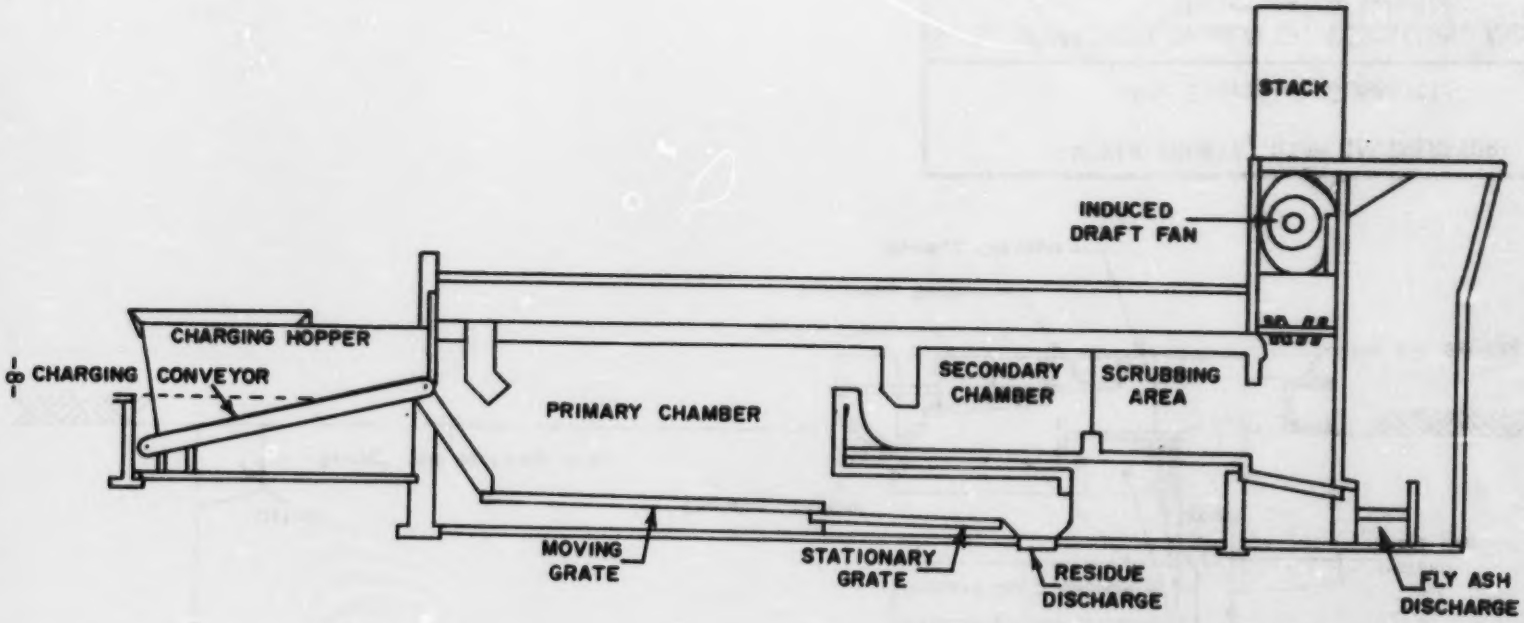
Design. The incinerator was designed as a 300 ton per 24 hour plant based on solid waste having a gross heating value of 5,000 Btu per pound. The plant has two 150 ton per 24 hour (6.25 tons per hour) furnaces completely independent except for a common residue discharge conveyor. The dumping floor and furnace equipment are completely enclosed in a metal building (Figure 2).

The incinerator building is located about 50 yards south of the northern boundary of the property. The physical plant is in a sheet metal building 190 feet long overall and 128 feet wide. The building is divided into the receiving and storage area and the furnace area. The receiving and storage area is 120 feet by 128 feet with a maximum roof height of 30 feet and is a completely clear, paved floor for dumping, storage, and handling of all incoming solid waste. Maximum practical capacity of the receiving area is estimated at 250 tons. Entrance and exit of all vehicles is through doors measuring 18 feet wide by 22 feet high. An office and sanitary facilities are in an enclosed area approximately 12 feet by 20 feet in size located against the front plant wall between the access doors. The remainder of the plant, measuring 60 feet by 70 feet, contains the two furnaces and their ancillary equipment.

Furnaces. The furnaces are physically identical (Figure 3). Each furnace is charged by a chain drive pan type conveyor 18 feet long and 7 1/2 feet wide rising at a 45° angle. The conveyor speed is variable from 0.85 to 2.0 feet per minute which corresponds to charging rates of 3.55 to 7.0 tons per hour.



WEBER COUNTY, UTAH INCINERATOR Side Elevation Schematic		
U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE Public Health Service Bureau of Solid Waste Management Division of Technical Operations		
May, 1969	Fig. 2	Not to Scale



WEBER COUNTY, UTAH INCINERATOR Combustion Unit Schematic		
U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE Public Health Service Bureau of Solid Waste Management Division of Technical Operations		
May, 1969	Fig. 3	Not to Scale

The primary combustion chamber is 28 feet long, 10 feet wide, and 14 feet high. Refractory self-supporting walls are built of 6 layers of 2700 F fire brick and the suspended roof is entirely castable refractory. The expected operating temperature at the design capacity is 1800 F.

The solid waste charged falls onto a moving grate section 10 feet wide and 16 feet long. This grate is sloped downward at 1 inch per foot. The entire grate moves as a unit forward and backward with a 29 inch stroke. The frequency of reciprocation is variable to permit a net forward speed of 0 to 5 feet per minute with a completely loaded grate. Material is advanced on the grate as it moves backward against the bulk of charged material and the back plate. Residence time in the furnace is from 30 to 45 minutes. The moving section consists of steel plate sections bolted to the supporting members. The individual sections have approximately twenty 3/16 inch holes per square foot uniformly spaced to permit the distribution of underfire air.

The moving grate is followed by a stationary grate section 12 feet in length. This section receives combustion air only by draft from the primary combustion chamber and from air leakage into the furnace from stoking doors and the residue conveyor ports. This grate serves to increase the total furnace residence time, aids in the completion of combustion, and begins the cooling of the solid residue.

Residue Handling. At the end of the stationary grate section the residue falls onto a steel conveyor which transports it to the outside of the building where it is dumped into a truck for transport to the disposal site. A series of spray nozzles are located over the conveyor to extinguish flames, cool the residue, and prevent the light particles from being blown about as the residue is transported to the disposal site. Water drains freely from the residue as the truck is being filled and is collected at a drop inlet below the conveyor. From this point, it is piped to percolation ponds adjacent to a slough tributary to the Weber River. The residue is trucked to an old quarry located about a quarter of a mile from the incinerator. The residue is dumped and periodically leveled. One edge of the fill is progressing into a lagoon fed by ground water. Water from the lagoon drains through a slough, past the residue quench water effluent pond, and into the Weber River.

Combustion Air. An underfire air fan supplies combustion air to the furnace through the 3/16 inch holes in the moving grate section. Furnace draft is aided by induced draft fans immediately below the stacks and is regulated by the adjustable dampers at the back of the furnace. No overfire air is supplied to the furnace. The underfire air fans, one per furnace, supply a maxium of 11,000 cubic feet per minute of combustion air at a normal operating pressure of 1 inch water. The gaseous products of combustion pass from the primary combustion chamber over a bridge wall, under a drop arch, and into the secondary combustion chamber. This secondary combustion chamber measures 12 feet long, 10 feet high, and is 12 feet wide at the entrance and 15 1/2 feet wide at the exit.

Fly Ash Scrubbing. From the secondary combustion chamber the gas stream passes through a scrubbing area that is 10 feet high, 15 1/2 feet wide, and 6 1/2 feet long. Forty-two castable refractory columns, each 12 inches in diameter, are situated on staggered centers in 4 lateral rows that create a tortuous path and increase the effective impingement surface area. Directly in front of the column area the gas stream passes through a sheet of water emanating from a slot in the roof that extends across the full width of the chamber. The slot is fed by keeping a section of the external chamber roof flooded. Water is delivered by a single pump per furnace at approximately 350 gallons per minute. In addition to the water passing through the slot, a series of light sprays operated off the municipal water supply are maintained between the slot and the columns. These sprays are a safety device to help cool the gas stream and protect the induced draft fans in the event of water pump failure. The gas stream carries much of the moisture with it as it passes through the sheet of water and sprays. This enables the columns to maintain a wetted surface. At the end of the scrubbing section the gas stream is deflected by a bank of tubes through the induced draft fan and exits through 10 foot high stub stacks to the atmosphere. These induced draft fans, one per stack, have a rated capacity of 57,000 cubic feet per minute.

Scrubbing water flows by gravity into a divided concrete settling basin. The first half of the basin is 21 1/2 feet long by 3 1/4 feet wide with an overflow pipe 5 feet above the flat bottom. The second half of the basin is identical to the first but is equipped with a wooden-flighted collector-conveyor which drags settled solids up an

incline for deposition in a pile outside of the building. The first half of the basin is cleaned out when the incinerator is shut down for weekly maintenance. The settling basins for each furnace have a common overflow pipe to accommodate excess water at times when cooling needs cause make up water flow to exceed evaporative losses. The overflow is piped to the east edge of the plant site to percolation ponds similar to the quench water ponds.

Instrumentation. Each furnace is equipped with a control panel with direct reading, non-recording gauges to assist the operator in regulating the furnaces. The gauges provide instantaneous readings of stack draft, secondary chamber draft, underfire air draft, and temperature measurements. The primary chamber temperature gauge is connected to a light warning system showing green up to 1800 F, yellow from 1800 F to 1840 F, changing to red above 1840 F. This gauge may also be switched to monitor stack temperatures.

Operation. As conditions dictate, system variables must be manually adjusted to effect changes in furnace operations, since the facility lacks automatic control. System variables having an influence on the furnace conditions that can be regulated by the operator are:

1. feed conveyor speed
2. solid waste mositure content (by adding water)
3. reciprocating grate speed
4. underfire air feed rate
5. gas velocity through the furnace

In practice, the reciprocating grate speed and the underfire air feed rate are normally never changed. Also, the feed conveyor speed is normally kept constant although the feed rate during the 1 to 2 hour start-up period is controlled by operating the conveyor intermittently. Thus, the solid waste moisture content and the gas velocity through the furnace remain as the major variables for control of the furnace conditions.

The primary furnace condition requiring control for effective trouble free operation is furnace temperature. Temperature control is achieved by regulating the amount of heat retained in the furnace. By opening dampers between the furnace and the induced draft fan less gas is pulled through the furnace which tends to increase the temperature in the furnace. By closing the dampers the full capacity of the induced draft fan can be used to draw gaseous products of combustion through the furnace at a maximum rate. This transports more heat out of the furnace, which reduces the temperature.

The moisture content of the solid waste can be increased by adding water at the feed conveyor. The addition of water slows ignition by increasing the heat of vaporization requirement, thereby reducing the furnace temperature. These two control methods are used in combination to maintain desired operating conditions.

The fairly common incinerator problems of ash slag accumulation on the furnace walls and clinker formation on the grates have been effectively solved. Air is directed along the walls and apparently is sufficient to keep the wall temperature below the ash fusion temperature. To prevent clinker formation and adhesion to the grates, close control is maintained over the furnace temperature. In addition, the relatively large volume

of air passing through the grates helps keep the fuel bed temperature next to the grates below the slag melting point. Experience with this plant has shown that clinkering problems occur if furnace temperatures remain over 2200 F for a substantial period of time. For a short period of time when the facility was new, it was operated using overfire air. During this period both slagging on the walls and clinkering on the grates were experienced. It was thought that the overfire air produced a cooling effect that caused these problems. Actually, the overfire air probably increased the wall temperature to the ash fusion point and, at the same time, the proportionately reduced air flow rate through the grates would have allowed higher temperatures to occur at the grate surface causing slag to melt and adhere to the surface. To correct this problem the overfire air system was eliminated.

The incinerator is open to the public from 5:00 a.m. to 6:00 p.m. Monday through Friday, 5:00 a.m. to 4:00 p.m. Saturday and 5:00 a.m. to 1:00 p.m. Sunday. This schedule is followed all year except for closing on Thanksgiving, Christmas, and New Year's day. The incinerator staff normally includes 10 full-time employees who regularly perform all supervisory, operating, and maintenance duties. The actual hours of operation are dependent upon the amount of wastes received. During the study period this was less than 24 hours per day. The weekly work schedule is divided basically into 8 hour shifts of two men each with the exception of Friday. Normally on Friday no waste is burned and all 10 men work on one shift doing the required weekly maintenance.

METHODS AND PROCEDURES

Solid Waste. All solid waste delivered to the incinerator in the seven day period beginning 5:00 a.m., Saturday, April 20 through 6:00 p.m., Friday, April 26 was weighed and recorded. Gross and tare weights of all vehicles were determined by using a temporary scale having a capcity of 50 tons and a 40 foot platform. The residue and fly ash were weighed in the same manner. The weights of solid waste received, amounts burned, and burning time were all recorded for calculation of the plant capacity, furnace burning rates, and efficiencies.

After considering firsthand experiences and reviewing literature for the types of categories used, the material was separated into the following categories:

1. food wastes
2. garden wastes
3. paper products
4. plastic, leather, rubber
5. textiles
6. wood
7. metals
8. glass and ceramics
9. ash, dirt, rocks, etc.

Categories 1 through 6 are defined as combustible and categories 7 through 9 are defined as noncombustibles.

Eleven samples ranging in size from 200 pounds to 1700 pounds were taken with a front end loader from the storage pile to determine the composition of the waste. Each sample was dumped on a cleaned area of the dumping floor, immediately separated by hand into the categories previously described, and the weight of each component determined.

Three smaller samples of solid waste were taken near the end of each day of stack testing. Approximately a 5 cubic foot sample of

visually representative material was obtained from the stored waste. The samples were separated and the non-combustible components removed. The combustibles were then shipped to the laboratory for analysis of moisture, ash, volatiles, and heat content.

Furnace Residue. Samples of the furnace residue were collected for determination of its composition and the efficiency of the incinerator. One sample was taken each day during a period of normal operation coincident with the stack test. Water sprays over the residue conveyor were turned off to permit the collection of dry samples. Samples were collected in a 55 gallon drum, weighed, and allowed to cool overnight. The fines were separated by shaking the entire sample on a 1/2 inch mesh screen. The material retained on the screen was then separated by hand into metals, unburned combustibles, glass and ceramics, and rocks. The portions were weighed; the unburned combustibles and fines were returned to the laboratory; and the remainder was discarded. The fines and unburned combustibles were analyzed for ash, volatiles, and heat content.

Liquid. Grab and composite samples of the liquid effluents from the incinerator were taken throughout the study. Samples were taken from the residue conveyor drainage, fly ash scrubber water settling basin overflow, and the lagoon adjacent to the residue disposal site. Composite samples of the residue conveyor drainage were taken in proportion to the component flow rates which were determined by time-volume measurements. The remaining sources were sampled by grab sampling. Laboratory analyses included chemical and physical analyses.

Stack. The stack effluents from both furnaces were sampled to determine the amount of particulate matter discharged with the stack gases. A series of 8 particulate samples, 4 from each stack, was taken over 2 days of normal operation. During this time the incinerator personnel were requested to operate the plant by their normal routine. A second series of 3 samples was taken from the stack effluent of furnace #1 under normal burning conditions but with an increase in scrubber water estimated at 75 percent. This was done to investigate the potential for increasing the degree of particulate control by this means. A third series of 3 samples was taken from the stack effluent of furnace #2 while operating at lower than normal furnace charging rates. This was done to determine if the particulate emission concentration is dependent upon the burning rate. An Orsat apparatus was used to determine the amount of carbon monoxide, carbon dioxide, and oxygen. The procedure for all stack effluent sampling was based on that described in the "Specifications for Incinerator Testing at Federal Facilities".[1]

Fly Ash. One composite sample of fly ash was collected during the testing period from the pile at the end of the chain-flight conveyor. This sample was returned to the laboratory for proximate analyses.

Laboratory Procedures. The combustible components of the solid waste samples returned to the laboratory were processed through a hammer-mill which reduced the waste to about 1-inch maximum dimension. This ground

product was spread on a plastic sheet and thoroughly mixed. The sample was then successively quartered and remixed with alternate quarters discarded. The process was repeated until a final sample of 3 to 4 pounds was obtained.

The incinerator residue samples returned to the laboratory, consisting of the unburned combustibles and fine material (everything but the metals; glass and ceramics; and ash, dirt, and rocks) were prepared for analyses by mixing and quartering as above to reduce the sample size to 3 to 5 pounds. The fly ash samples did not require pretreatment.

After grinding and/or sample size reduction, the solid waste, residue, and fly ash samples were analyzed according to the same procedure. Approximately 100 gram portions were dried at 70 C to constant weight for determination of moisture content. The entire dried samples were then cooled and ground in a Wiley mill* to pass through a 2 millimeter mesh sieve. The volatile and ash determinations were performed on the dried samples according to the procedures outlined in Appendix A of Municipal Refuse Disposal.[2] The heat content of the dried solid samples was determined in a Parr Adiabatic calorimeter using the method described in "Operating the Adiabatic Calorimeter".[3]

All analyses of the liquid samples were performed according to methods published in Standard Methods for Examination of Water and Wastewater.[4]

The analysis of the stack effluent particulate samples was performed according to procedures described in "Specifications for Incinerator Testing at Federal Facilities".[1]

*Mention of company or product name does not constitute endorsement by the Department of Health, Education and Welfare.

RESULTS AND EVALUATION

Solid Waste. A total of 818.7 tons of solid waste was delivered to the incinerator in the 7 day study period from 5:00 a.m., Saturday, April 20 to 6:00 p.m., Friday, April 26, 1968 (Table I). This is an average of 116.9 tons per day.

TABLE I

Solid Waste Received

(Tons)

Sun.	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.	Total	Avg.
12.4	128.3	133.4	156.1	143.4	150.6	94.5	818.7	116.9

The composition of solid waste (Table II and Table III) delivered to the incinerator during the study period was based on 11 samples taken during 4 days.

The composition of the samples (Table IV) returned for the proximate analysis (Table V) was determined so that all the data could be converted to an "as received" basis.

TABLE II

Weight of Solid Waste Component Per Sample

(Pounds)

Sample No.	1	2	3	4	5	6	7	8	9	10	11
Component											
Combustibles											
Food Wastes	38	156	67	26.5	63.0	88	248	6	13	12	35
Garden Wastes	2	16	55	15.5	60.0	31	166	6	5	9	4
Paper Products	505	869	499	472.5	899.5	579	1012	177	147	118	190
Plastic, Rubber and Leather	9	37	21	36.5	30.5	27	23	10	12	6	6
Textiles	17	13	14	21.5	27.0	21	32	3	7	15	2
Wood	52	21	5	26.5	27.5	27	18	3	2	6	8
Subtotal	623	1112	661	599.0	1107.5	773	1499	205	186	166	245
Noncombustibles											
Metals	48	104	93	64.0	150.5	73	99	43	20	12	34
Glass & Ceramics	17	75	47	29.0	92.5	43	66	7	11	6	12
Ash, Rocks, Dirt	12	123	66	57.5	144.0	17	36	15	14	16	19
Subtotal	77	302	206	150.5	387.0	133	201	65	45	34	65
TOTAL	700.0	1414.0	867.0	749.5	1494.5	906.0	1700.0	270.0	231.0	200.0	310.0

TABLE III

PERCENTAGE OF SOLID WASTE COMPONENT PER SAMPLE
(By Weight)

Sample No.	1	2	3	4	5	6	7	8	9	10	11	Avg.
Component												
Combustibles												
Food Wastes	5.4	11.0	7.7	3.5	4.2	9.7	14.6	2.2	5.6	6.0	11.3	7.4
Garden Wastes	0.3	1.1	6.3	2.1	4.0	3.4	9.8	2.2	2.2	4.5	1.3	3.4
Paper Products	72.2	61.5	57.7	63.0	60.3	63.9	59.5	65.6	63.6	59.0	61.3	62.5
Plastic, Rubber, and Leather	1.3	2.6	2.4	4.9	2.0	3.0	1.4	3.7	5.2	3.0	1.9	2.8
Textiles	2.4	0.9	1.6	2.9	1.8	2.3	1.9	1.1	3.0	7.5	0.6	2.4
Wood	7.4	1.5	0.6	3.5	1.8	3.0	1.0	1.1	0.9	3.0	2.6	2.4
Subtotal	89.0	78.6	76.3	79.9	74.1	85.3	88.2	75.9	80.5	83.0	79.0	80.9
Non-Combustibles												
Metals	6.9	7.4	10.7	8.5	10.1	8.1	5.8	15.9	8.6	6.0	11.0	9.0
Glass & Ceramics	2.4	5.3	5.4	3.9	6.2	4.7	3.9	2.6	4.8	3.0	3.9	4.2
Ash, Rocks, Dirt	1.7	8.7	7.6	7.7	9.6	1.9	2.1	5.6	6.1	8.0	6.1	5.9
Subtotal	11.0	21.4	23.7	20.1	25.9	14.7	11.8	24.1	19.5	17.0	21.0	19.1

TABLE IV

COMPOSITION OF SOLID WASTE SAMPLES RETURNED FOR PROXIMATE ANALYSIS

Component	Sample No. 1		2		3	
	lbs	%	lbs	%	lbs	%
Combustibles	23.6	77.1	13.4	66.9	12.9	88.4
Metal	1.6	5.3	3.5	17.5	1.6	11.2
Glass	2.8	9.0	3.0	15.0	0.1	0.4
Ash	2.6	8.6	0.1	0.6		
Total	30.6	100.0	20.0	100.0	14.6	100.0

TABLE V

PROXIMATE ANALYSIS OF SOLID WASTE

Sample No.	Moisture* %	Volatiles (dry) %	Ash (dry) %	Heat Content (as sampled) Btu/lb
1	20	65.8	34.2	4240
2	20	53.4	46.6	3640
3	20	78.3	21.7	5340
Average	20	65.8	34.2	4410

* Assumed

The laboratory moisture content analyses did not produce results that agreed with observed wetness of samples in the field. The conclusion drawn was that the samples lost moisture while in transit to the Cincinnati laboratories. Therefore, a moisture content of 20 percent has been assumed and used in all pertinent calculations in this report. An example calculation is shown in Appendix A.

Burning Rate. The burning rates (Table VI) of the furnaces were determined from the charging conveyor speeds and the time of operation. The total hours of operation were taken as the time from light-off each morning to the time the feed conveyors were cleared each evening. One hour was subtracted from this total to allow for the time while the furnaces were being heated to their normal operating temperatures. However, once operating temperatures were attained, the feed conveyors were run at a constant speed. Therefore, the calculated average burning rates are reasonably close to the actual conditions at any time of operation. Design burning rate is 6.25 tons per hour per furnace.

TABLE VI

BURNING RATE

Day	Tons Received	Tons Burned	Hours of Burning Time	Furnace Burning Rate (tons/hr)	Furnaces Operating
Saturday	94.5	0	---	---	---
Sunday	12.4	0.8	---	---	2
Monday	128.3	126.4	10.33	6.1	1 and 2
Tuesday	133.4	129.4	12.17	5.3	1 and 2
Wednesday	156.1	147.2	13.25	5.6	1 and 2
Thursday	143.4	152.9	13.17	5.8	1 and 2
		10.8	2.25	4.8	2
		6.2	1.75	3.6	2
Friday	150.6	0	---	---	---

The burning rates for both furnaces were assumed to be equal as the feed conveyors were operated at the same speed. The exception to this is for furnace No. 2 on Thursday. In this case the feed conveyor speed was intentionally reduced for experimentation and a known weight of waste was fed over the burning times indicated. This resulted in the reduced burning rates of 4.8 and 3.6 tons per hour. The average burning rate for the period of Monday through Thursday when both furnaces were operated was 5.7 tons per hour per furnace.

Residue. The residue composition (Table VII) was determined on a dry basis except for sample number one which contained a slight amount of moisture. The analysis for volatiles, ash, and heat content (Table VIII)

were done on a dry basis. Because dry samples of residue were obtained and the weight of the total residue hauled to the disposal site was wet, a moisture content of 15 percent was assumed and used in the efficiency calculations. An example calculation is shown in Appendix B.

Fly Ash. The analysis of the composite sample showed the fly ash contained 64.9 percent moisture, 14.0 percent volatiles, 86.0 percent ash, and a heat content of 180 Btu per pound. The ash, volatiles, and heat content data are on a dry basis.

TABLE VII

RESIDUE COMPOSITION

Component	Sample 1		2		3		Average
	lbs	%	lbs	%	lbs	%	%
Metals	50.5	35.2	26.2	18.3	23.3	18.1	23.9
Glass & rocks	44.0	30.7	49.5	34.4	37.0	28.7	31.2
Unburned combustibles and fines	49.0	34.1	68.1	47.3	68.5	53.2	44.9
Total	143.5	100.0	143.8	100.0	128.8	100.0	100.0

TABLE VIII

PROXIMATE ANALYSIS OF RESIDUE

Sample No.	Moisture*	Volatiles	Ash	Heat Content
	%	%	%	Btu/lb
1	15	3.8	96.2	130
2	15	2.1	97.9	190
3	15	2.0	98.0	190
Average	15	2.6	97.4	170

* Assumed

Plant Efficiency. The weight reduction and volatile reduction (Table IX) achieved by the plant were calculated by using the dry weight of solid waste and residue. The heat released was calculated by using the heat content of the dry residue and the heat content of the wet solid waste. These calculations are shown in Appendix C.

TABLE IX

PLANT EFFICIENCY

Efficiency	Percent
Weight Reduction	61
Volatile Reduction	98
Heat Released	99

Particulate Emissions. The particulate data (Table X) from the stack tests include the material from the ether and chloroform extract and the residue remaining after evaporation of the impinger water.

The data of major interest are those from tests 1 through 9 conducted during normal operating conditions. The data from tests 2, 4, and 6 were not included because of difficulties experienced in the sampling process. The average particulate emissions observed during normal operation were 0.55 grains per standard cubic foot corrected to 12 percent carbon dioxide or 60.5 pounds of particulate per hour per furnace.

The particulate emissions observed at the reduced feed rates and when the scrubber flow was increased were significantly higher than those at normal operating conditions. However, these values are more of experimental interest at this time and do not relate to this facility's normal emissions.

Liquid Effluents. The wastewater characteristics (Table XI) for the plant were determined by analyzing 4 composite samples of the residue conveyor discharge, daily grab samples of the scrubber basin effluent, and a grab sample from the west pond (residue conveyor water), east pond (scrubber basin water), and tap water.

The waste water from the residue conveyor and scrubber basin are currently discharged to small ponds. No overflow was observed from these ponds during the study. The ponds are located in uncompacted sand and gravel which allow a high rate of percolation. This, together with evaporation, explains why no overflow was observed.

The quarry that is being filled with residue contains a lagoon fed by a natural spring. The lagoon effluent discharges to the Weber River. A grab sample of the effluent was obtained for analysis. The reported average flow of the Weber River is 150,000 gallons per minute.

TABLE X

STACK EFFLUENT DATA PER FURNACE

Test No.*	Length of test (min.)	Furnace No.	Gas composition (%)			Excess air (%)	gr/scf			lb/part./1000 lb dry flue gas			lb/ton waste	lbs/hr	Comment
			CO_2	O_2	N_2		Existing CO_2	12% CO_2	50% EA	Existing CO_2	12% CO_2	50% EA			
1	85	1	4.5	15.7	79.8	295	0.26	0.69	0.68	0.48	1.29	1.27	12.3	75.3	
3	30	2	4.8	15.7	79.5	295	0.24	0.59	0.62	0.44	1.10	1.16	12.0	68.1	Normal operation
5	40	2	5.1	15.7	79.2	300	0.23	0.54	0.62	0.44	1.04	1.18	11.2	68.3	
7	24	2	4.6	15.8	79.6	305	0.23	0.60	0.62	0.43	1.13	1.16	12.5	69.7	
8	26	1	3.9	16.3	79.8	340	0.16	0.49	0.47	0.30	0.92	0.89	7.2	40.3	
9	35	1	4.7	15.4	79.9	270	0.15	0.39	0.38	0.29	0.74	0.71	7.4	41.4	
Avg.	—	-	4.6	15.8	79.6	270	0.21	0.55	0.56	0.40	1.04	1.06	10.4	60.5	
10	32	2	3.3	16.8	79.9	390	0.40	1.46	1.31	0.75	2.74	2.47	24.6	117.3	Reduced feed rate
11	34	2	3.0	17.6	79.4	525	0.36	1.43	1.48	0.67	2.69	2.79	25.5	121.6	
12	30	2	3.4	16.4	80.2	345	0.18	0.64	0.54	0.34	1.21	1.02	17.8	63.2	
Avg.	—	-	3.2	16.9	79.9	420	0.31	1.18	1.11	0.59	2.21	2.09	22.6	100.7	
13	32	1	3.6	15.7	80.7	280	0.29	0.97	0.74	0.55	1.82	1.38	13.8	80.3	Two scrubber pumps operating
14	31	1	5.3	14.3	80.4	205	0.40	0.90	0.81	0.74	1.68	1.52	19.5	112.9	
15	30	1	5.0	15.1	79.9	250	0.37	0.88	0.86	0.98	1.64	1.64	18.4	107.0	
Avg.	—	-	4.6	15.0	80.4	245	0.35	0.92	0.80	0.76	1.71	1.51	17.2	100.1	

*The results from Test No. 2, 4, and 6 were incomplete.

TABLE XI

WASTEWATER CHARACTERISTICS

Analysis	Units	Residue conveyor discharge					Scrubber basin effluent				West pond	East pond	Lagoon effluent	Tap water
		Mon.	Tue.	Wed.	Thurs.	Avg.	Tue.	Wed.	Thurs.	Avg.				
Temperature	°C	30	30	30	30	30								
Turbidity	Turbidity units	480	60	175	100					67			15	
Conductivity	μ mhos/cm	2,050	3,900	3,900	2,145	3,000	6,800	7,300	7,200	7,100	1,550	1,550		460
pH		11.0	11.0	11.2	8.4		3.9	3.8	4.2		7.5	7.4	7.8	7.7
Total suspended solids	mg/1	1,680	2,090	2,315	1,350	1,860	850	1,195	2,010	1,350	30	30	200	1.0
Total disolved solids	mg/1	1,295	1,290	1,185	1,365	1,285	5,660	5,720	6,090	5,825	1,050	1,075	300	280
Alkalinity	mg/1 $CaCO_3$	158	70	200	52	120	0.0	0.0	4.0	1.0	1,040	1,040		364
Bicarbonate	mg/1 HCO_3	9	4.0	106	62									
Carbonate	mg/1 CO_3	91	40	135	0.8									
Hydroxide	mg/1 OH	1.5	1.6	1.6	0.04									
Calcium	mg/1 Ca	136	156	162	220	168								
Chloride	mg/1 Cl	374	401	425	485	421	2,155	2,333	2,404	2,297	206	210		21
Hardness	mg/1 $CaCO_3$	342	398	460	624	456	3,100	3,430	3,780	3,433	645	631		
Iron	mg/1 Fe (total)	26	46	23	20	29								
Manganese	mg/1 Mn	0	0	0	0.02	0								
Nitrate	mg/1 NO_3	3.9	0.4	1.2	1.8	1.8								
Phosphate	mg/1 PO_4	0.8	0.3	0.4	0.4	0.5	32.2	46.0	76.2	51.5	3.0	1.8		0.1

TABLE XI CONTINUED

WASTEWATER CHARACTERISTICS

Analysis	Units	Residue conveyor discharge Mon.	Tue.	Wed.	Thurs.	Avg.	Scrubber basin effluent Tue.	Wed.	Thurs.	Avg.	West pond	East pond	Lagoon effluent	Tap water
Sulfate	mg/l SO_4	189	307	176	233	226	688	625	862	725	131	140		41
Surfactant	mg/l ABS	0.05	0.0	0.0	0.0									
BOD	mg/l	370	110	35	110									
COD	mg/l	1,090	890	1,210	925	1,030							100	

Cost Analysis. The following cost analysis is based upon information provided by Weber County officials. Data for calendar year 1968 was obtained.

Several assumptions were made in developing the 1968 Incinerator Costs (Table XII). The first assumption concerned the amount of solid waste processed during the year. Weight measurements made during the 7 day field study indicated that an average of 116.9 tons of waste was received per day. Assuming that this is an average daily rate, the annual amount would be 42,700 tons. The next assumption concerned the useful life of the physical plant and vehicles. Based on information reported for other facilities, a life of 20 years was used for the physical plant and 5 years for the trucks and frontend loaders. Although the incinerator was paid for in full, upon construction, i.e., without the need for bonding, the funds involved represented potential earnings in the form of interest. For this reason, a value has been included to represent the interest had the facility been supported by a bond issue at 3.2 percent for a 20 year period. The capital cost of the vehicles was added to the capital cost of the plant when the interest was calculated.

In a further effort to define expenditures involved in incinerator operation, an analysis has been made (Table XIII) on the allocation of cost by activity. The activities (cost centers) used are receiving, volume reduction, and effluent handling and treatment. Additionally, a breakdown of repair and maintenance expenses by cost centers is included (Table XIV).

TABLE XII

1968 INCINERATOR COSTS

Item	($)	($/ton)	(%)
Direct Labor (including fringe benefits at 16 percent)	75,184	1.76	43.8
Utilities (electric, gas, etc.)	17,352	0.41	10.1
Parts and Supplies	12,509	0.29	7.3
Vehicle Operating Expenses	1,739	0.04	1.0
External Repair Charges	7,346	0.17	4.2
Disposal Charges (actual or allocated)	700	0.01	0.4
Overhead	11,326	0.27	6.6
Total Annual Operating Cost	126,156	2.95	73.4
Plant Depreciation ($471,659 over assumed 20 year life)	23,582	0.55	13.7
Interest on $501,867 (at assumed 3.2 percent on a 20 year bond)	16,059	0.38	9.4
Vehicle Depreciation (assuming 5 year life on $30,208 investment)	6,041	0.14	3.5
Total Annual Ownership and Financing Cost	45,682	1.07	26.6
Total Annual Cost	171,838	4.02	100.0

TABLE XIII

OPERATING COST BREAKDOWN BY COST CENTERS

Item	Costs ($)	Costs (%)
Receiving		
Direct Labor	25,062	19.9
Utilities	0	0.0
Vehicle Operating Expense	1,564	1.2
Repairs & Maintenance	6,824	5.4
Overhead	3,775	3.0
Total	37,225	29.5
Volume Reduction		
Direct Labor	35,504	28.2
Utilities	8,597	6.8
Repairs & Maintenance	21,641	17.2
Overhead	5,348	4.2
Total	71,090	56.4
Effluent Handling and Treatment		
Direct Labor	4,176	3.3
Utilities	8,755	6.9
Vehicle Operating Expense	175	0.1
Disposal Charges	700	0.6
Repairs & Maintenance	3,406	2.7
Overhead	629	0.5
Total	17,841	14.1
Total Operating Cost	126,156	100.0

TABLE XIV

REPAIR AND MAINTENANCE COST BREAKDOWN BY COST CENTERS

Item	Costs ($)
Labor	10,442
Parts	12,509
External Charges	7,346
Overhead	1,574
Total	31,871

Allocation	$	Percent
Receiving	6,824	21.4
Volume Reduction	21,641	67.9
Effluent Treatment	3,406	10.7
Total	31,871	100.0

REFERENCES

1. National Center for Air Pollution Control. Specifications for incinerator testing at Federal facilities. Durham, N.C., U.S. Department of Health, Education, and Welfare, Oct. 1967. 35 p.

2. American Public Works Association. Municipal refuse disposal. 2nd ed. Chicago, Public Administration Service, 1966. Appendix A. p. 375-399.

3. Parr Instrument Company, Operating the adiabatic calorimeter. In Oxygen bomb calorimetry and combustion methods. Technical Manual No. 130. Moline, Ill., 1960. p. 30-32.

4. American Public Health Association, American Water Works Association, and Water Pollution Control Federation. Standard methods for the examination of water and wastewater; including bottom sediments and sludges. 12th ed. New York, American Public Health Association, Inc., 1965. 769 p.

ACKNOWLEDGEMENTS

The Bureau of Solid Waste Management wishes to express its appreciation to the staff of the Weber County Incinerator and, in particular, to Mr. Grant Anderson, Director, Weber County Refuse Engineering Department, whose constant assistance was essential to the successful completion of this field study.

The assistance of the Utah Division of Health and, in particular, Dr. Grant Wynn, Mr. Clyde Hopkins, and Mr. Clifford Crane, in furnishing personnel, laboratory analyses, and supplies was also instrumental to the study and greatly appreciated.

Members of the field study team were:

James S. Bridges
Dennis E. Carruth
John J. Giar
Tobias A. Hegdahl
H. Lanier Hickman, Jr.
Edward L. Higgins
Harry R. Little
Raymond E. Loebker
Albert E. O'Connor
Jerry E. Ongerth
James W. Polich
John T. Talty
Morris G. Tucker

The Division of Research and Development, Bureau of Solid Waste Management, provided additional laboratory support necessary for the successful completion of this study.

APPENDIX A

EXAMPLE CALCULATIONS FOR THE ASH, VOLATILE, AND HEAT CONTENT OF THE SOLID WASTE

Using the data from solid waste sample number 2, these example calculations show the methods used to calculate the moisture, ash, volatile and heat content of the total sample. For these calculations, the assumption was made that the noncombustibles contained no moisture, no heat, and were considered as "ash".

It was assumed that the solid waste contained 20 percent moisture. The moisture content of the combustibles is calculated by the following equation:

$$\text{Percent moisture in total sample} = \left(\frac{\text{lb combustibles}}{\text{lb waste}}\right)\left(\frac{\text{lb moisture}}{\text{lb combustibles}}\right)\left(100.0\right)$$

$$20 = (0.67)\left(\frac{\text{lb moisture}}{\text{lb combustibles}}\right)\left(100.0\right)$$

$$\frac{\text{lb moisture}}{\text{lb combustibles}} = 0.298$$

Because the ash and volatile content of the total sample is calculated on a dry basis, the separation data (Table IV) must be converted to a dry basis by the following equation:

$$\text{Percent dry component} = \left(\frac{\text{lb wet component} - \text{lb moisture in component}}{\text{dry sample weight}}\right) 100.0$$

These calculations are summarized in the following table:

TABLE A-1

Conversion of the Separation Data to a Dry Basis

Component	Wet weight (lb)	Percent moisture	Moisture (lb)	Dry weight (lb)	Percent by dry weight
Combustibles	13.4	29.8	4.0	9.4	58.6
Noncombustibles	6.6	0	0	6.6	41.4
Total	20.0	-	4.0	16.0	100.0

The laboratory only analyzed the combustible portion of the solid waste (Table A-2).

TABLE A-2

Laboratory Analysis of the Combustible Portion of the Solid Waste

Sample No.	Moisture* (%)	Volatiles (%)	Ash (%)	Heat (Btu/lb, MAF)
1	23.2	92.1	7.9	8,060
2	13.9	91.2	8.8	8,500
3	15.8	91.6	8.4	8,530

*Assumed to be incorrect (see RESULTS AND EVALUATION - Solid Waste).

To calculate the volatile content of the total sample, the ash content of the noncombustibles must be accounted for. This can be done through the following method.

$$\text{Percent volatile in total sample} = \left(\frac{\text{lb volatiles}}{\text{lb dry combustibles}}\right)\left(\frac{\text{lb dry combustibles}}{\text{lb dry waste}}\right)(100)$$

Percent volatiles in total sample = (0.912) (0.586)(100.0)= 53.4

Percent ash in total sample = 100.0 - percent volatiles

Percent ash in total sample = 100.0 - 53.4 = 46.6

The laboratory reported the heat content for the combustibles on a moisture and ash free basis. Thus the moisture content and noncombustibles in the total sample and ash in the combustibles must be accounted for when calculating the heat content of the total sample on an "as received" basis. This is done by the following method:

$$\text{Heat content of total sample} = \left(\text{heat content of combustibles}\right)\left[1 - \left(\frac{\text{moisture content of total sample}}{100.0}\right) + \frac{\text{noncombustibles in total sample} + \text{ash in the combustibles}}{100.0}\right]$$

The moisture content was assumed as 20.0 percent; from the separation data, 33.0 percent of the waste was noncombustibles; the ash in the combustibles must be converted to a wet basis for the total sample by the following method:

$$\text{Percent ash in combustibles on a wet basis} = \left(100\right)\left(\frac{\text{lb ash}}{\text{lb dry combustibles}}\right)$$

$$\left(\frac{\text{lb dry combustibles}}{\text{lb dry sample}}\right) \div \left(\text{wet sample weight}\right)$$

$$\text{Percent ash in combustibles on a wet basis} = (100)\,\frac{(0.088)\,(9.4)}{20.0} = 4.1$$

$$\text{Heat content of total sample} = (8{,}500)\left[1 - \left(\frac{20.0 + 33.0 + 4.1}{100.0}\right)\right]$$

$$\text{Heat content of total sample} = (8{,}500)\,(0.429) = 3{,}650\ \text{Btu/lb}$$

APPENDIX B

EXAMPLE CALCULATIONS FOR THE ASH, VOLATILE, AND HEAT CONTENT OF THE RESIDUE

By using the composition data (Table VII) and the data from the laboratory analyses (Table B-1) of the fines and unburned combustibles, these calculations show the method used to calculate the ash, volatile, and heat content of residue sample number 2.

TABLE B-1

Laboratory Analysis of the Fines and Unburned Combustibles

Sample No.	Moisture (%)	Volatiles (%)	Ash (%)	Heat (Btu/lb MAF)
1	19.4	12.8	87.2	3,400
2	< 0.1	4.4	95.6	9,040
3	< 0.1	3.8	96.2	9,400

Residue sample number 1 contained some moisture but sample 2 and 3 did not. The composition data for sample 1 was converted to a dry basis, but this was not required for samples number 2 and 3. For sample number 2, the composition on a dry basis was 18.3 percent metals, 34.4 percent glass and rocks, and 47.3 percent fines and unburned combustibles.

The volatile, ash, and heat content of the total sample on a dry basis is calculated by the following methods:

$$\text{Percent volatiles in total sample} = \left(\frac{\text{lb volatiles}}{\text{lb fines}}\right)\left(\frac{\text{lb fines}}{\text{lb sample}}\right)\left(100.0\right)$$

$$\text{Percent volatiles in total sample} = (0.044)\ (0.473)\left(100.0\right) = 2.1$$

Percent ash in total sample = 100.0 - percent volatiles = 100.0 - 2.1

Percent ash in total sample = 97.9

$$\text{Heat content in total sample} = \left(\frac{\text{Btu}}{\text{lb volatiles}}\right)\left(\frac{\text{lb volatiles}}{\text{lb sample}}\right)$$

Heat content in total sample = (9,040) (0.021) = 190 Btu/lb

APPENDIX C

PLANT EFFICIENCY CALCULATIONS

These calculations show the methods used to determine the percent weight reduction, the percent volatile reduction, and the percent heat released. The following data were used:

Residue	Fly Ash	Particulates per Furnace	Solid Waste
201 tons(wet)	4.6 tons(wet)	60.5 lb/hr	573 tons(wet)
15% moisture	64.9% moisture		20% moisture
171 tons(dry)	3.0 tons(dry)		458 tons(dry)
2.6% volatiles	14.0% volatiles		65.8% volatiles
4.45 tons volatiles	0.4 tons volatiles		302 tons volatiles
170 Btu/lb (dry)	180 Btu/lb (dry)		4,410 Btu/lb (wet)
48.9 hrs of burning time			

$$\text{Percent weight reduction} = \left[1 - \left(\frac{\text{dry residue wt + dry particulate wt}}{\text{dry solid waste wt}} + \frac{\text{dry wt of fly ash} + \text{dry wt of wastewater solids}}{\text{dry solid waste wt}}\right)\right](100.0)$$

$$\text{Percent weight reduction} = \left\{1 - \left[\frac{171 + 2\left(\frac{60.5}{2{,}000}\right)(48.92) + 3.0 + \text{not measured}}{458.2}\right]\right\}(100.0)$$

$$\text{Percent weight reduction} = \left[1 - \left(\frac{177}{458.2}\right)\right](100.0) = 61.2$$

$$\text{Percent volatile reduction} = \left[1 - \left(\frac{\begin{matrix}\text{dry wt of volatiles} \\ \text{in residue}\end{matrix} + \begin{matrix}\text{dry wt of volatiles in} \\ \text{particulates}\end{matrix}}{\text{dry volatile wt in solid waste}} + \frac{\begin{matrix}\text{dry wt of volatiles} \\ \text{in fly ash}\end{matrix} + \begin{matrix}\text{dry wt of volatiles in} \\ \text{wastewater}\end{matrix}}{\text{dry volatile wt in solid waste}}\right)\right](100.0)$$

$$\text{Percent volatile reduction} = \left[1 - \left(\frac{4.4 + \text{not measured} + 0.4 + \text{not measured}}{302}\right)\right](100.0)$$

$$\text{Percent volatile reduction} = \left[1 - \left(\frac{4.8}{302}\right)\right] 100.0 = 98.4$$

$$\text{Percent heat released} = \left[1 - \left(\frac{\begin{matrix}\text{heat in} \\ \text{residue}\end{matrix} + \begin{matrix}\text{heat in} \\ \text{fly ash}\end{matrix} + \begin{matrix}\text{heat in} \\ \text{particulate}\end{matrix} + \begin{matrix}\text{heat in} \\ \text{wastewater}\end{matrix}}{\text{heat in solid waste}}\right)\right](100.0)$$

$$\text{Percent heat released} = \left\{1 - \left[\frac{(170)(171)(2{,}000) + (180)(3.0)(2{,}000) + \text{N.M.} + \text{N.M.}}{4{,}410(573)2{,}000}\right]\right\}(100.0)$$

$$\text{Percent heat released} = \left[1 - \left(\frac{59.22 \times 10^6}{5{,}054 \times 10^6}\right)\right](100) = 98.8$$